

Type 2 diabetes and weight loss following Gastric Banding and Gastric Bypass

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De acordo com as normas da revista: Obesity Surgery

2016

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Abstract

Background: Bariatric Surgery has been proposed as a treatment option for patients with Type 2 Diabetes Mellitus (T2DM). Most existing studies had a relatively short term follow-up. This study aims to provide information about weight loss and T2DM remission at 3 years and at the last observation after Adjustable Gastric Banding (AGB) or Roux-en-Y Gastric Bypass (RYGB).

Methods: Retrospectively we collected data about body weight and T2DM control and medication before and after bariatric surgery in patients who underwent AGB (43 patients) or RYGB (48 patients) in Hospital de Santo António between 1997 and 2012. Patients were evaluated at 3 years and at the last observation after surgery. To define T2DM and T2DM remission or improvement we used ADA's HbA1c diabetes diagnostic cut-off values.

Results: At 3 years after surgery, EBMI was 47% and 64% and T2DM remission or improvement was 51% and 50% for AGB and RYGB, respectively. HbA1c $\leq 6.5\%$ occurred in 91% and 71% of patients in AGB and RYGB group, respectively ($p < 0.05$).

At the last observation, EBMI was 38% and 64% and T2DM remission or improvement was 40% and 52% for AGB and RYGB, respectively. HbA1c $\leq 6.5\%$ occurred in 86% and 83% of patients in AGB and RYGB group, respectively ($p = 0.946$).

Conclusion: AGB and RYGB provide weight loss and T2DM remission in obese patients with T2DM at 3 years and at longer follow-up. At 3 years and at the last observation, RYGB provided greater %EBMI ($p < 0.01$) but there weren't statistically significant differences between both surgical groups concerning T2DM remission ($p = 0.130$) or T2DM remission or improvement ($p = 0.912$).

Keywords: Bariatric Surgery; Weight Loss; Type II Diabetes Mellitus;

Introduction

Type 2 Diabetes Mellitus (T2DM) is an obesity-related condition [1-3]. World Health Organization (WHO) estimates that diabetes will be the 7th leading cause of death by 2030 [4].

According to the American Diabetes Association (ADA) 2016 recommendations, bariatric surgery is a possible way to control obesity and diabetes in adults with BMI $> 35 \text{ Kg/m}^2$ [5]. Several studies [6-8] have associated bariatric surgery in diabetic obese patients with T2DM improvement or remission. Bariatric surgery promotes greater weight loss and T2DM remission relative to patients receiving only non-surgical treatment [9-13].

In Hospital de Santo António (HSA), adjustable gastric banding (AGB) and Roux-en-Y gastric bypass (RYGB) are the bariatric procedures more frequently performed. Comparative studies [6-8, 14, 15] have shown that weight loss and T2DM remission after bariatric surgery are higher in patients who underwent RYGB than in patients who underwent AGB.

Although not all patients achieve T2DM remission after bariatric surgery, most of them improve glycemic control and reduce the use of diabetes medications [6, 7, 13, 16-19].

Long-term studies to analyze outcomes of bariatric procedures on diabetes disease are important [20-22]. Therefore, this study aims to provide information about weight loss and T2DM remission at 3 years after AGB or RYGB in HSA but also at the last follow-up.

Methods

This is a retrospective cohort study from a cohort of obese patients with T2DM who performed bariatric surgery in a single center (HSA, Portugal).

The inclusion criteria were: having T2DM, a preoperative BMI $> 35 \text{ Kg/m}^2$, to have AGB or RYGB as the first bariatric procedure and at least 1 observation of follow-up in a period ≥ 2 years after surgery. We defined T2DM using ADA criteria [5]. Participants were at least 18 years old.

Retrospectively, we collected data (sex, age, weight, height, hemoglobin A1c level (HbA1c), fasting plasma glucose (FPG) and class number and dosage of diabetes medications) from medical records, before and after surgery. We consider as preoperative data all information collected from medical records up to 3 years prior to the operative date. As annual follow-up in the first 3 years after surgery, we used medical records up to ± 6 months and if there were more than 1 record, we used the one closest to 12, 24 or 36 months, respectively. To analyze the outcomes at 3 years after surgery, we used records after the second year (≥ 2 years) and closest to the 36th month. To

analyze long term outcomes of bariatric surgery, we also collected data at the last observation after surgery. For the AGB patients who underwent conversion to RYGB and in patients who died, we considered as last observation, the last examination before conversion or death, respectively.

For statistical analysis we used SPSS 22.0. We performed Little's MCAR test to search for any relationship between the missingness of the data and any values, observed or missing, from the database [23, 24]. To identify differences among both groups and for paired samples we used parametric tests for continuous variables. For categorical variables we used Chi-square test and McNemar's test. Whenever we couldn't collect information about diabetes medications, we considered the worse outcome referring to T2DM remission and diabetes medications for those patients (no remission and no decrease of diabetes medications) [25]. We considered that results were statistically significant when $p < 0.05$. Data are presented as mean \pm SD with minimum and maximum values.

Study outcomes were weight loss, T2DM remission, glucose control and use of diabetes medications after bariatric surgery. To define T2DM remission we used "HbA1c criteria": T2DM remission if HbA1c $< 5.7\%$ and T2DM improvement if HbA1c $5.7 - 6.5\%$, in both cases without hypoglycemic treatment during at least one year; no remission if these criteria weren't met [26]. Recurrence from remission was defined as the proportion of patients who didn't present T2DM remission criteria at the last observation among those who were in remission at 3 years after surgery and whose last observation wasn't in the third year after surgery.

For this type of study formal consent isn't required. This study was approved by Centro Hospitalar do Porto's Ethics Committee.

Results

We included 43 patients in the AGB group and 48 patients in the RYGB group. Detailed information about patient's selection and missing data can be seen in Fig. 1.

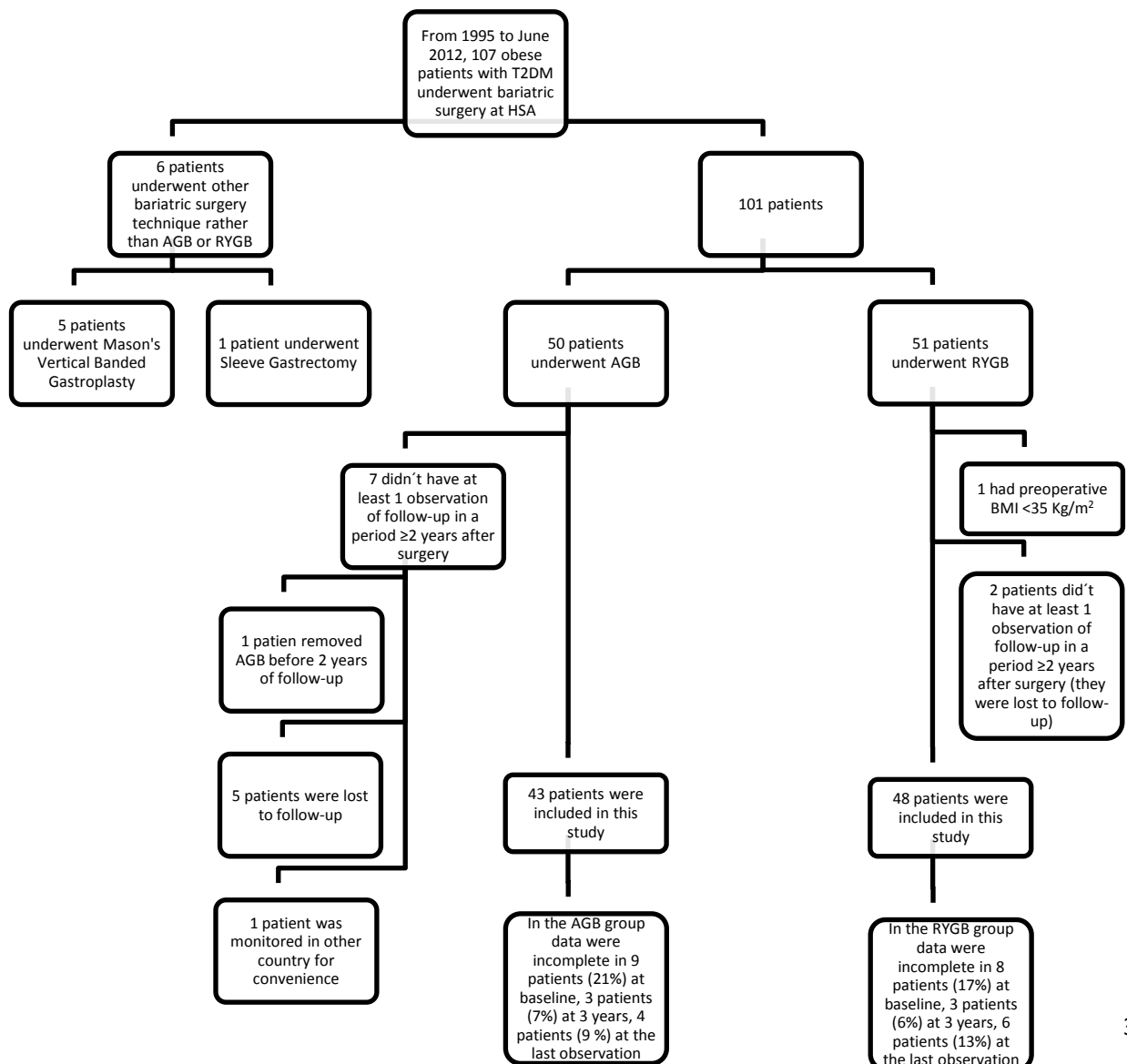


Fig.1 - Detailed information about patient selection. T2DM = type 2 diabetes mellitus; AGB = adjustable gastric banding; RYGB = roux-en-Y gastric bypass;

During the follow-up there were 3 deaths at 2.3, 3.6 and 11.6 years of follow-up. Eight AGB patients underwent surgery of conversion to RYGB with mean length of follow-up of 8.3 ± 4.20 (2.83 to 16.58) years and the reasons of conversion were esophageal failure in 3 patients, band perforation in 1 patient, pouch dilation in 1 patient, band slippage in 1 patient and failure of weight loss in 2 patients.

Missing values analysis shows that data may be assumed to be missing completely at random (MCAR) and missingness was assumed not to matter for the analysis [23, 24].

Baseline characteristics Table 1 shows baseline characteristics of patients of both surgical groups. Comparing baseline characteristics of both groups, there weren't differences in age, sex, weight, height, HbA1c, FPG and in the proportion of patients taking any diabetes medications. There were differences in BMI, excess weight, excess BMI, proportion of patients taking insulin and the proportion of patients with more than 1 class of diabetes medications. The AGB group was heavier but had lower proportion of patients under insulin and lower proportion of patients under more than 1 class of diabetes medications.

Table 1 - Baseline characteristics of patients of both surgical groups (AGB and RYGB).

Baseline characteristics	AGB	RYGB	P
	n=43	n=48	
Woman/Man	35 (81%)/8 (19%)	39 (81%)/ 9 (19%)	0.986
Age (years)	50 ± 8.21 (35 to 67)	50 ± 8.65 (34 to 65)	0.872
Weight (Kg)	130.0 ± 32.28 (95.2 to 244.0)	119.2 ± 17.20 (91.0 to 174.2)	0.053
Height (m)	1.62 ± 0.09 (1.49 to 1.84)	1.62 ± 0.10 (1.47 to 1.97)	0.843
BMI (Kg/m ²)	50 ± 11.03 (35 to 89)	45 ± 5.07 (35 to 59)	0.022*
Excess Weight (Kg)	71.4 ± 30.19 (38.8 to 181.3)	60.2 ± 13.72 (35.3 to 97.2)	0.029*
Excess BMI (Kg/m ²)	25 ± 11.02 (10 to 64)	20 ± 5.07 (10 to 34)	0.022*
	n=36	n=42	
HbA1c (%)	7.1 ± 2.14 (4.6 to 15.4)	7.8 ± 1.88 (5.3 to 11.9)	0.116
HbA1c $\leq 6.5\%$	19 (53%)	14 (33%)	0.133
	n=42	n=46	
FPG (mg/dL)	150 ± 72.81 (76 to 404)	154 ± 60.51 (86 to 320)	0.736
	n=42	n=48	
No DMm / Any DMm	4 (9.5%) / 38 (90.5%)	1 (2%) / 47 (98%)	0.282
	n=42	n=48	
No insulin/Insulin	39 (93%) / 3 (7%)	34 (71%) / 14 (29%)	0.008*
≤ 1 class / >1 class DMm	26 (62%) / 16 (38%)	17 (35%) / 31 (65%)	0.012*

* $p < 0.05$; AGB = adjustable gastric banding; RYGB = roux-en-Y gastric bypass; BMI = body mass index; HbA1c = hemoglobin A1c; FPG = fasting plasma glucose; DMm = diabetes medication; P = p value for differences among two surgical groups;

During the first years, AGB was the only bariatric procedure performed but, gradually, RYGB became the most frequent procedure.

Length of Follow-up Weight loss was analyzed at approximately 3 years after surgery (2.89 ± 0.42 (1.50 to 3.41) years in the AGB patients and 3.00 ± 0.28 (2.19 to 3.68) years in the RYGB patients) ($p = 0.113$).

T2DM remission, glucose control and use of diabetes medications were also analyzed at approximately 3 years after surgery (2.85 ± 0.50 (1.50 to 3.95) years in the AGB group and 2.93 ± 0.37 (1.97 to 3.97) years in the RYGB group) ($p = 0.403$).

The last observation where weight loss was evaluated was 8.03 ± 4.05 (1.90 to 16.89) years after surgery for the AGB group and 4.57 ± 1.34 (2.51 to 10.16) years after surgery for the RYGB group. The last observation where T2DM remission, glucose control and use of diabetes medications were evaluated was 7.49 ± 4.33 (1.90 to 17.04) years after surgery.

years after surgery for the AGB group and 4.24 ± 1.40 (2.18 to 10.13) years after surgery for the RYGB group. The AGB group had a longer follow-up ($p < 0.01$).

Weight Loss At 3 years, mean BMI reduction in the AGB patients was 11.08 Kg/m^2 ($p < 0.01$) and mean excess BMI loss (EBMIL) was 47% ($p < 0.01$). In the RYGB patients, mean BMI reduction was 13.04 Kg/m^2 ($p < 0.01$) and mean EBMIL was 64% ($p < 0.01$). The RYGB group had a greater %EBMIL at 3 years ($p < 0.01$). At the last observation after bariatric surgery, in the AGB patients, mean BMI reduction was 8.9 Kg/m^2 ($p < 0.01$) and mean EBMIL was 38% ($p < 0.01$). In the RYGB patients, mean BMI reduction was 13.1 Kg/m^2 ($p < 0.01$) and mean EBMIL was 64% ($p < 0.01$). At the last observation, the RYGB patients had a greater BMI reduction and %EBMIL ($p < 0.01$) (Table 2).

Table 2 – Mean change of body weight and BMI, %EWL and %EBMIL at each time before and after surgery in both groups.

	AGB (n=43)		RYGB (n=48)		AGB vs RYGB
	Mean Change \pm SD (min to max)	P ^a	Mean Change \pm SD (min to max)	P ^a	
At 3 years					
Body Weight (Kg)	-29.1 ± 20.01 (-89.8 to +5.0)	< 0.01	-34.0 ± 13.11 (-63.50 to 5.80)	< 0.01	0.180
BMI (kg/m ²)	-11.1 ± 7.34 (-27.4 to +2.1)	< 0.01	-13.0 ± 5.34 (-26.0 to +2.0)	< 0.01	0.153
% EWL	41.6 ± 23.91 (-10.7 to +100.06)	< 0.01	56.6 ± 18.58 (-9.32 to 90.91)	< 0.01	< 0.01
% EBMIL	46.9 ± 27.23 (-12 to +110)	< 0.01	63.8 ± 21.26 (-10 to +106)	< 0.01	< 0.01
At the last observation					
Body Weight (Kg)	-23.5 ± 22.61 (-89.0 to +28.0)	< 0.01	-34.0 ± 12.99 (-54.60 to 5.80)	< 0.01	< 0.01
BMI (kg/m ²)	-8.9 ± 8.22 (-32.7 to +10.0)	< 0.01	-13.1 ± 5.35 (-23.0 to +2.0)	< 0.01	< 0.01
% EWL	33.9 ± 25.37 (-15.5 to +99.2)	< 0.01	56.9 ± 18.99 (-9.32 to +90.91)	< 0.01	< 0.01
% EBMIL	38.0 ± 28.43 (-16 to +119.7)	< 0.01	64.3 ± 21.83 (-10 to +108)	< 0.01	< 0.01

AGB = adjustable gastric banding; RYGB = roux-en-Y gastric bypass; BMI = body mass index; EBMIL = excess body mass index loss; n=number of patients; P^a = p value to change; P^b = p value for comparison between two surgical groups.

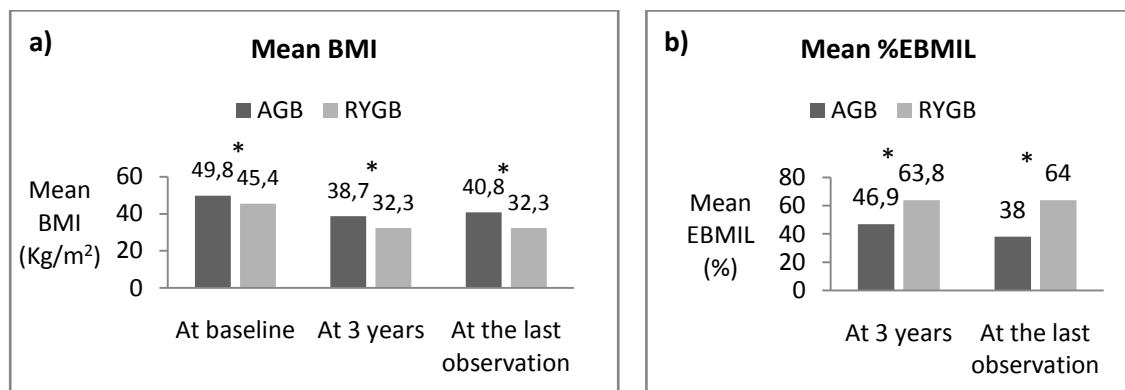


Fig. 2 - **a)** Mean BMI at baseline, at 3 years and at the last observation after surgery according surgical procedure (8.03 ± 4.05 (1.90 to 16.89) years after surgery for the AGB group and 4.57 ± 1.34 (2.51 to 10.16) years after surgery for the RYGB group). **b)** Mean %EBMIL at 3 years and at the last observation after surgery according surgical procedure (8.03 ± 4.05 (1.90 to 16.89) years after surgery for the AGB group and 4.57 ± 1.34 (2.51 to 10.16) years after surgery for the RYGB group). * $p < 0.05$ to difference between two surgical groups.

Diabetes Remission At 3 years, remission or improvement in accordance with “HbA1c criteria” was observed in 22 (51%) AGB patients and in 24 (50%) RYGB patients. At the last observation, remission or improvement was observed in 17 (40%) AGB patients and in 25 (52%) RYGB patients. Fig. 3 shows detailed information about T2DM remission and improvement rates. There weren’t statistically significant differences between both surgical groups. Between the third year and the last observation there weren’t new cases of remission in the AGB group but there were 3 (13%) new cases of remission among the 23 RYGB patients who weren’t in remission at 3 years after surgery. At the last observation, T2DM recurrence was observed in 11 (50%) AGB patients and in 2 (12%) RYGB patients among those who were in remission at 3 years after surgery. Sustained T2DM remission was greater in patients who underwent RYGB ($p < 0.05$). Analyzing the patients considered with T2DM recurrence, in AGB group, 5 patients changed from T2DM remission to improvement, 1 patient had HbA1c=6.6% without diabetes medications and 5 patients were on noninsulin agents with mean HbA1c=5.5 \pm 0.75

(4.7 to 6.6) % at the last observation. In RYGB group, 1 patient changed from T2DM remission to improvement and 1 patient had HbA1c= 5.5% on metformin at the last observation.

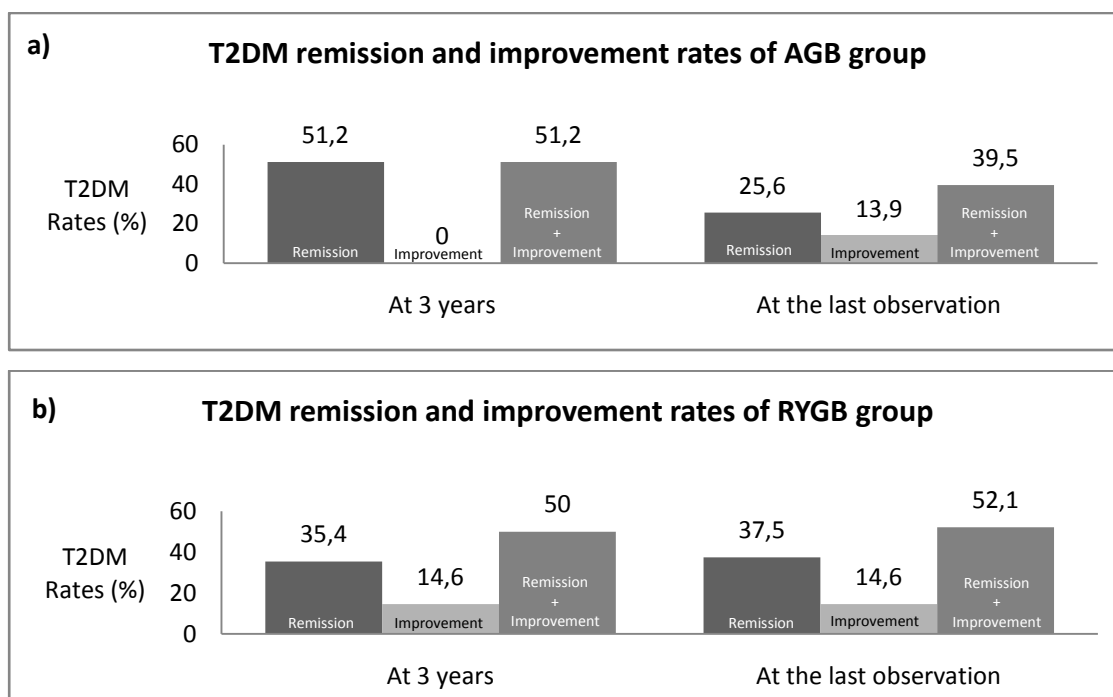


Fig 3 – Rate of T2DM remission, improvement and remission or improvement at 3 years and at the last observation after surgery according to the surgical procedure. **a)** T2DM remission, improvement and remission or improvement rates of AGB group at 3 years and at the last observation (7.49 ± 4.33 (1.90 to 17.04) years after surgery). **b)** T2DM remission, improvement and remission or improvement rates of RYGB group at 3 years and at the last observation (4.24 ± 1.40 (2.18 to 10.13) years after surgery).

Glycemic Control At baseline, the mean HbA1c wasn't significantly different in the AGB group when compared to the RYGB group (7.1 ± 2.1 vs. 7.8 ± 1.9 , $p=0.116$) but the HbA1c in the AGB cohort was significantly lower than in the RYGB group at 3 years (5.3 ± 1.1 vs. 6.0 ± 0.7 , $p<0.01$) (Fig.4).

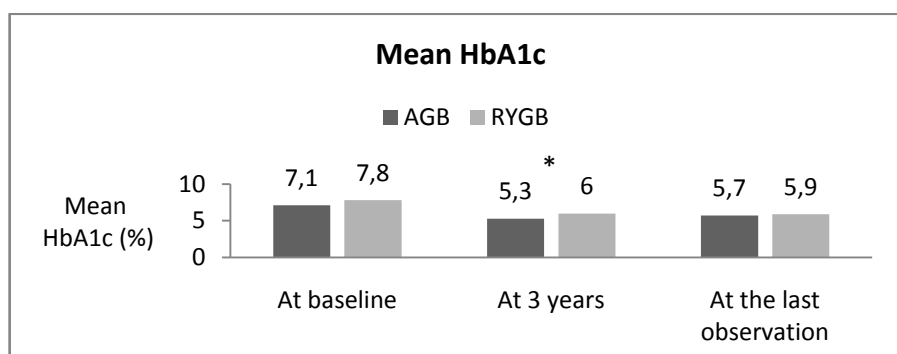


Fig.4 – Mean HbA1c (%) at baseline, at 3 years and at the last observation after surgery according to the surgical procedure (7.49 ± 4.33 (1.90 to 17.04) years after surgery for the AGB group and 4.24 ± 1.40 (2.18 to 10.13) years after surgery for the RYGB group). * $p<0.01$ to difference between two surgical groups

At 3 years after surgery, the proportion of patients with $HbA1c \leq 6.5\%$ increased from baseline in both groups ($p<0.01$) from 53% to 91% in AGB and from 33% to 71% in RYGB group. The proportion of patients with $HbA1c \leq 6.5\%$ was higher in the AGB group ($p<0.05$). At the last observation, 37 (86%) AGB and 40 (83%) RYGB patients had HbA1c level $\leq 6.5\%$ ($p=0.946$). Changes in HbA1c and FPG are reported in table 3.

Table 3 – Changes in HbA1c and FPG at 3 years and at the last observation stratified by surgery type (7.49±4.33 (1.90 to 17.04) years after surgery for the AGB group and 4.24±1.40 (2.18 to 10.13) years after surgery for the RYGB group).

	AGB			RYGB			AGB vs RYGB
	n	Mean Change±SD (min to max)	P ^a	n	Mean Change±SD (min to max)	P ^a	P ^b
At 3 years							
HbA1c (%)	36	-1.7±2.30 (-10.0 to +3.3)	<0.01	42	-1.7±1.62 (-6.3 to +0.2)	<0.01	0.960
FPG (mg/dL)	41	-51.8±79.58 (-286.0 to 185.0)	<0.01	43	-50.4±50.22 (-205.0 to +38.0)	<0.01	0.925
At the last observation							
HbA1c (%)	36	-1.3±2.19 (-9.2 to +1.9)	<0.01	42	-1.83±1.64 (-6.4 to +0.3)	<0.01	0.261
FPG (mg/dL)	38	-47.2±76.61 (-268.0 to +147.0)	<0.01	41	-54.8±51.86 (-201.0 to +19.0)	<0.01	0.606

AGB = adjustable gastric banding; RYGB = roux-en-Y gastric bypass; n = number of patients; P^a = p value to change; P^b = p value for comparison between two surgical groups

Diabetes Medication At 3 years and at the last observation, there was a significant decrease in the proportion of patients on diabetes medications in both surgical groups when compared to the baseline (p<0.01). In accordance with the AGB or RYGB group, 50% and 57% of patients, respectively, went from using insulin or oral diabetes medications to no medication at 3 years after surgery. At 3 years and at the last observation there weren't differences between both groups in the proportion of patients on insulin as well as in the proportion of patients on more than 1 class of diabetes medications.

The mean number of different classes of diabetes medications decreased significantly after surgery (p<0.01) from 1.4±0.86 and 2.3±1.21 at baseline to 0.6±0.71 and 0.6±0.87 at 3 years and to 0.7±0.82 and 0.6±0.87 at the last observation in AGB and RYGB, respectively.

Table 4 shows more detailed information about the use of diabetes medications in each time of follow-up according to the surgical procedure and glycemic control.

Table 4–Use of diabetes medications before and after bariatric surgery in both groups (AGB and RYGB).

		Time of Follow-up		
		At baseline	At 3 years	At the last observation
		AGB (n=42) RYGB (n=48) % (n)	AGB (n=41) RYGB (n=48) % (n)	AGB (n=43) RYGB (n=48) % (n)
AGB patients	On diabetes medications	90 (38)	46 (19)	58 (25)
	- HbA1c≤6.5%	43 (18)	37 (15)	47 (20)
	- HbA1c>6.5%	33 (14)	10 (4)	12 (5)
	- ms HbA1c	14 (6)	0 (0)	0 (0)
	Off diabetes medications	10 (4)	54 (22)	42 (18)
	- HbA1c≤6.5%	0 (0)	54 (22)	40 (17)
	- HbA1c>6.5%	7 (3)	0 (0)	2 (1)
RYGB patients	On diabetes medications	98 (47)	42 (20)	42 (20)
	- HbA1c≤6.5%	29 (14)	19 (9)	27 (13)
	- HbA1c>6.5%	58 (28)	23 (11)	15 (7)
	- ms HbA1c	10 (5)	0 (0)	0 (0)
	Off diabetes medications	2 (1)	58 (28)	58 (28)
	- HbA1c≤6.5%	0 (0)	52 (25)	56 (27)
	- HbA1c>6.5%	0 (0)	6 (3)	2 (1)
	- ms HbA1c	2 (1)	0 (0)	0 (0)

AGB = adjustable gastric banding; RYGB = roux-en-Y gastric bypass; HbA1c = hemoglobin A1c; n=number of patients; ms HbA1c = missing data to HbA1c

Conclusion

During the first years of this study, AGB was the only bariatric procedure performed in HSA but, gradually, RYGB became the most frequent procedure. Our practice is in line with results from Buchwald, et al [27] who assessed the numerical status of bariatric surgery and showed a decrease in the AGB percentage whereas RYGB rose from 2003 to 2011 in Europe.

Our results show that both surgical groups provided significant decrease in BMI at 3 years after surgery as well as at the last observation (mean follow up time: 5 years after RYGB and 8 years after AGB). These decreases were similar to the ones reported by Yu et al [8] at mean time of follow-up of 2<year<5 after surgery.

Our results show that mean decreases in BMI, from baseline to 3 years, were similar among both surgical groups. Buchwald et al reported that gastric bypass can provide higher decrease in BMI than AGB [7]. Our results (similar decreases) can be due to AGB patients being heavier than RYGB patients at baseline.

In accordance with other studies [7, 8], the RYGB group had a greater %EWL and %EBMIL at 3 years although having lower BMI and lower excess weight at baseline.

At the last follow-up visit, BMI reduction, %EWL and %EBMIL were significantly higher with RYGB than with AGB but AGB follow-up is longer. At 5 years after surgery, several studies [8, 28] have reported similar results. However, other studies [20, 22] have showed no significant difference in %EWL between the two surgical groups at 3 years and also at longer follow-up.

According to several reviews [6, 7, 29, 30], bypass provides greater T2DM remission than banding procedures. However, our results at 3 years and at the last observation didn't show differences between both surgical procedures as reported in other studies [22, 31-34]. Considering the worse metabolic profile of RYGB patients, characterized by a higher proportion of insulin users and higher proportion of patients on more than 1 class of diabetes medications at baseline, the achievement of a similar rate of T2DM remission at 3 years suggests that RYGB may be more beneficial than AGB for diabetic patients.

At baseline AGB patients were heavier than RYGB ones and although some studies [35-37] did not find an association between BMI at baseline and T2DM remission, other study [22] found a positive association between T2DM remission at 5 years and BMI at baseline, so this can justify the similar T2DM remission rates in our results independently of the surgical procedure.

In our study, RYGB patients had lower T2DM remission rates than those previously reported in the literature [38-41]. AGB patients had similar or higher rates than those reported in other studies [38, 39, 41]. Despite some studies use other criteria [42], we used a simpler criteria to define T2DM remission [26]. Levi et al [26] showed that there weren't differences in T2DM remission rates whichever the criteria used so this shouldn't be the reason for lower rates in our RYGB patients. Lower HbA1c at baseline can predict T2DM remission [7, 22, 43] and in our study, RYGB patients' mean HbA1c was 7.8 at baseline while in patients of others studies (that reported higher T2DM remission rates after gastric bypass) the mean HbA1c was 6.7% [40] and 7.0% [39] at baseline. Non use of insulin at baseline can predict T2DM remission [43] and only 71% of RYGB participants in our study were off insulin while in other studies [39, 40] there were 90% of participants off insulin. Younger age can also predict T2DM remission [43] and the mean age of RYGB patients of our study was 50 years old while the mean age of participants in other study [38] (with higher T2DM remission rates) was 43 years old. At baseline, we didn't assess the duration of T2DM and serum insulin levels of participants – factors that have been associated with remission rates after bariatric surgery [35, 43] - in each surgical group. To better understand the reasons of these differences it will be necessary to know the state of all predictors of remission in our patients at baseline. On the other hand, after surgery, there were some patients with good glycemic control but on metformin (as adjuvant of weight loss, for example). Therefore, we don't know if these patients would or not be in remission if they stopped metformin, and this can lead to underestimation of T2DM remission rates and/or overestimation of T2DM recurrence rates.

At the last observation of AGB patients (mean follow-up time: 7.49 years) T2DM remission rate was 26% comparatively to 0% [28] and 40% [44] at 5 years after surgery, in two others studies. At the last observation of RYGB patients (mean follow-up time: 4.24 years) T2DM remission rate (38%) was in line with rate reported by Brethauer et al (31%) [28] but was lower than rates previously reported at 5 years (68%) [12], (58%) [45] and even at 6 years (62% [46], 88% [47]), in others studies. AGB group had a longer length of follow-up. However, at the last observation, T2DM remission rate wasn't significantly different between AGB and RYGB, against the results reported by other authors [8].

T2DM recurrence rates in our study was 12% in the RYGB group at 4 years and 50% in the AGB group at 7.5 years. These findings are somewhat in conflict with several studies [28, 48, 49] that have reported higher T2DM recurrence rates in RYGB. Many factors have been reported as contributors to higher T2DM recurrence rates, such as being lighter [48] and being on insulin [49] at baseline and having lower %EWL [28] and having higher BMI after surgery [28, 48]. Comparing AGB and RYGB patients, AGB were heavier at baseline and fewer of them were on insulin but also had lower EWL and higher BMI at the last follow-up – so, these two last factors contribute to higher T2DM recurrence rate, although a study [49] reported that weight regain was a weak predictor. The higher

number of patients on insulin at baseline - factor associated with T2DM recurrence – and the shorter length of follow-up of RYGB patients can also be an explanation to our different rates comparing with previously reported rates. DM duration is other factor associated with T2DM recurrence [28] but we didn't assess this information.

As previously reported [19] there were many patients who didn't achieve T2DM remission but achieved glycemic control. HbA1c is the most widely accepted laboratory test for the measurement of glycemic control [50]. At 3 years, analyzing HbA1c independently of diabetes medications, in the AGB cohort it was significantly lower than in the RYGB group and more AGB patients achieved $HbA1c \leq 6.5$ than RYGB patients. This discordance between our results and most studies [39, 51] can result from the differences in use of diabetes medications at baseline between our surgical groups (at baseline, despite not having a lower HbA1c than the RYGB group, the AGB group had a lower proportion of patients on insulin and a lower proportion of patients on more than 1 class of diabetes medications).

At 3 years, 91% of AGB and 71% of RYGB patients achieved $HbA1c \leq 6.5$. These results seem better than results previously reported [13, 52] after gastric bypass. Panunzi et al [35] showed that HbA1c at baseline predicts glycemic control and this might be the reason of discordance between our results and the literature - RYGB patients in our study had $HbA1c$ mean = 7.8% at baseline while, in other study [13], patients had $HbA1c$ mean = 9%.

At the last observation the proportion of patients that achieved $HbA1c \leq 6.5$ was similar in both groups although AGB patients had a longer follow-up. At this length of follow-up, the proportion of patients with $HbA1c \leq 6.5$ was similar (in RYGB) or even higher (in AGB) than proportions previously reported of $HbA1c < 7\%$ at 5 five years [28]. This discordance can be due to a lower proportion of AGB patients on insulin at baseline in our study comparatively with AGB patients on insulin in that study.

Analyzing the use of diabetes medications, as we can observe in table 4, the absence of diabetes medications doesn't necessarily mean that it is not needed to achieve glycemic control, and this should be taken in consideration while analyzing this parameter.

After surgery, there was a significant decrease in the proportion of patients on diabetes medications from baseline in both groups, which is in line with others results reported in the literature [17].

In Makary et al [18], the proportion of patients that went from using insulin or oral diabetes medications to no medication at 3 years after surgery was 86.1% while in our study was 50% in AGB group and 57% in RYGB group at 3 years after surgery. Younger age and male sex were independently associated with cessation of the use of diabetes medications [18]. Although the mean age was 50 years in our study vs. 48 years in that study, only 19% of our participants were men while there were 25.5% male participants in that study, so this can be a reason to differences between our results and previously reported results in the literature.

There weren't statistically significant differences in the proportion of patients on insulin as well as in the proportion of patients on more than 1 class of diabetes medications between both groups, after surgery. However, RYGB patients had a significantly higher proportion of patients on insulin and/or more than 1 class of diabetes medications, at baseline, which could suggest that RYGB may provide more reductions in the use of diabetes medications than AGB in patients with T2DM.

As previously reported in literature [13, 18] the mean number of different classes of diabetes medications decreased significantly after surgery.

This study has some limitations. This is a study based in clinical practice where there is the need to conciliate hospital, physician and patient schedules. Consequently, appointment dates sometimes don't match with the recommended intervals. The retrospective nature of these data made it difficult to match patients in each group. In this study, patients were only matched to having T2DM, a $BMI > 35$ kg/m², and at least 2 years of follow-up. As a result, the AGB group was heavier and had fewer patients under insulin or under more than 1 class of diabetes medications than RYGB patients at baseline. As a result of the long duration of this study, data accuracy might experience variations due to changes in laboratorial equipment over the years. Weights were obtained from different physician office scales. Under the assumption that patients with incomplete data had worse outcomes (no T2DM remission and no diabetes medications improvement), the benefits of bariatric surgery in HSA might be underestimated.

In the comparison of two bariatric procedures other important outcomes should be analyzed, such as complications of both surgical procedures, for example.

In the future, it will be useful to perform this study with surgical groups paired in all characteristics at baseline to understand if in HSA a procedure provides effectively a better result in terms of weight loss and T2DM

remission than the other procedure. In addition, surgical groups should be analyzed with similar times of follow-up at last observation to compare more clearly the effects of both procedures at a longer follow-up.

In conclusion, our study demonstrated the efficacy of AGB and RYGB for weight loss and T2DM remission in obese patients with T2DM at 3 years and at longer follow-up.

At 3 years after surgery, RYGB provided greater %EBMIL but there weren't differences between both surgical groups concerning T2DM remission.

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